Proceedings of the 1st CIRP Industrial Product-Service Systems (IPS2) Conference, Cranfield University, 1-2 April 2009, pp261

Sensitivity Cost-Benefit Analysis to Support Knowledge Capture of Industrial Interests

A.M. Paci, M.S. Chiacchio
Istituto di Tecnologie Industriali e Automazione, Consiglio Nazionale delle Ricerche, Via dei Taurini 19,
Rome, 00185, Italy
augusta.paci@itia.cnr.it

Abstract
In strategic industrial fields, emerging technologies are evolving into strategic enabling technologies for next generation products and services (IPS2). To this end a new approach to market knowledge capture needs early impact assessment of costs and value benefits considering the broad variety of factors of sustainability in medium-long term. This paper presents the framework for new IPS2 and a new methodology for Sensitivity Cost-Benefit Analysis (SCBA). SCBA aims to evaluate new IPS2, based on RTD potential, applying the AHP (Analytic Hierarchy Process) technique. The evaluation results support stakeholders in market knowledge capture about new IPS2 based on new enabling technologies.

Keywords:
Cost-Benefit, Impact assessment, Production paradigms

1 INTRODUCTION

In strategic industrial fields of major European and regional interests, emerging technologies are evolving fast into strategic enabling technologies for the conception and development of next generation products and services.

Important initiatives are being undertaken at European and national level to coordinate public and private stakeholders. Multilevel studies promote the diffusion of these emerging pacing technologies for innovative industrial product-service systems (IPS2) and related business models.

In this context, the production and manufacturing of new products and services shall refer to market-oriented scenarios meeting and mutually reinforcing competitiveness and sustainability [1]. A new strategic technology represents a possible driver of change, for next generation of products and services to meet the challenge of sustainability, which is composed by economic, environmental, social and technological dimensions [2].

In the past, according to O.K. Mont, the concept of product-service systems included 'dematerialisation' as part of the today IPS2 [3]. Looking to new IPS2, 'dematerialisation' shall include pacing technologies to shape the 'entire process' for next generation products and services as a new framework for IPS2.

Today's IPS2 seek for efficiencies – such as: flexibility, mass-customisation, quality, high added value and cost reduction currently – referred as the new industrial production response paradigm meeting Vision and Strategic Research Agendas for new production [4] [5].

This paper presents the framework for scenarios of new IPS2 together with a new methodology for Cost-Benefit Analysis [6] – named SCBA (Sensitivity Cost-Benefit Analysis). The SCBA aims to evaluate the potential IPS2 in medium-long term market scenarios.

The novel framework considers that pacing technologies provide high value features of next generation of IPS2 to compete in existing markets with existing products and services.

In the K-economy, the industrial leadership in medium-long term of a pacing technology becomes a driver of change. The market exploitation needs knowledge capture for the analysis of prospective IPS2 ideas. The SCBA supports industrial innovation projects by market knowledge capture within scenarios development for an entire IPS2. It focuses on:

- the specific pacing technology potential of IPS2;
- the early impact assessment in today markets [7];
- time to market for rapid implementation in new markets;
- all sustainability related aspects (environmental, social, technological, and economical).

The scenarios, built through knowledge management methods and tools [8], involve all stakeholders (producers and buyers) in the design and development of next generation IPS2 and the technology life cycle.

The impact assessment outcomes support stakeholders in decision-making and business development of next generation of IPS2, with an overview of market pull and sustainability issues, drivers for change and new relationship among high technologies, producers-consumers, suppliers, regulations and society.

2 INDUSTRY INITIATIVES

The European Technology Platforms with the related Joint Technological Initiatives – the most important industry-led initiatives based on R&D priorities for technology sustainable development – cover strategic fields of broad and regional interests. Among these strategic industrial fields, the satellite industry has become a very important sector with a significant impact on the technological, social, economic and environmental aspects. Satellite communications have brought many benefits to society and citizens, in Europe and worldwide.

The space industry makes a vital contribution to the renewed Lisbon agenda for 'jobs and growth' and to the i2010 strategy for the European Information Society. Satellite can help build new markets – i.e. audiovisual and media new markets – and applications. Digital TV for example has already been broadcast over pan-European satellite systems for several years, with hundreds of digital TV programmes provided to European consumers. This sector contributes also to the 'energy and climate change' and 'social welfare' Lisbon objectives with initiatives, such as the wide footprints of satellites that help humanitarian organisations to respond to emergencies or disasters, wherever they occur. Satellite coverage may also be the only way to provide broadband connectivity to very remote areas, in the EU or globally, as shown by the recently announced EU Strategy for Africa.

In this context the role of the European Space Agency has developed the strong vision for the space sector. Particularly, Galileo and GMES initiatives demonstrate the multilevel commitment to the space industry [9] [10] [11].

ISI (Integral Satcom Initiative) European Technology Platform [12] was launched in 2006 and was established to bring together for the first time in a unified, industry-led forum all the research and technology aspects related to satellite communications, including mobile, broadband, and broadcasting applications. The purpose is to foster and develop the entire industrial sector, maximise the value of European research and technology development, and contribute to EU and ESA policies [13].

Studies are undertaken to analyse the introduction of new IPS2 and related business models into markets and to assess their impact. Among the impact assessment studies of new technologies for manufacturing roadmaps, aerospace industry demand has been analysed as one of manufacturing sectors examined, in terms of R&D needs within the FP6 Leadership SSA project [14] [15]. This study showed that aerospace sector's demand for new industrial response paradigms and new business models, together with the need to communicate everywhere and within a range of very different contexts.

In recent years, many studies, at European, national and local levels, have been carried out with particular reference to the use of the Galileo system. These studies aim to contribute to the development of value-added services and applications to fully exploit all possible potential of this system into markets. This development of services and applications aims to fulfil market expectations with the development of next generation IPS2 featuring high value services.

In particular, the following ones are the four Galileo services:

- The Open Service (OS) that provides position and timing performance; it is competitive with other GNSS systems.
- The Safety-of-Life Service (SoL) that improves the open service performance through the provision of timely warnings to the user when it fails to meet certain margins of accuracy (integrity).
- The Commercial Service (CS) that provides access to two additional signals, to allow for a higher data throughput rate and to enable users to improve accuracy.
- The Public Regulated Service (PRS) that provides position and timing to specific users requiring a high continuity of service, with controlled access.

This new scenario for the space sector requires innovative approaches to fully exploiting the high-value features of satellites, considering not only technological or economic/financial aspects, but also social and environmental issues. To this purpose the approach – proposed in the paper – considers a wide range of criteria to analyse the full potential of the new enabling technology.

This paper reports on the methodology – developed and applied in an evaluation study – for Galileo system to become the enabling technology for new IPS2 of the space sector.

3 THE SCBA FRAMEWORK

The theoretical framework, presented in this paper, aims to propose a new methodology, the SCBA, to evaluate the specific pacing technology that plays a strategic role in the value innovation process for next generation IPS2.

The SCBA framework for IPS2 considers that pacing technologies, by replacing key technologies, provide new features of the next generation of IPS2.

This framework refers to scenarios development that shows how to move from a starting situation of Leadership in technology towards the development of a new market for successful IPS2 (Figure 1).

In order to support the turning of pacing technologies into business, the SCBA enables supporting the evaluation of the potential IPS2 and market knowledge capture – by solving two special problems:

- potential competition with similar existing systems (existing markets, existing products, existing data,…);
- medium-long term horizon of the development of the next generation of IPS2 and its related difficulties (qualitative data, non-measurable data, strategic pacing technologies).

Previous methods to evaluate new product development for IPS2 have been oriented to analyse advanced technology product development and related introduction processes, in order to enhance a company's competitive advantage. The development in this field includes also the buyer-supplier perspective.

The SCBA considers the buyer-supplier perspective and enhances the involvement of all stakeholders (producers and consumers) right from the start – the design phase – of the development of next generation IPS2.

In addition, to help organizations make better decisions for the successful next generation of IPS2, the evaluation analysis requires consideration of whole market, integrating competitiveness perspective with the dimensions of sustainability.

Sustainability refers to broad variety of criteria. Being part of the analysis, suitable and manageable groups of criteria allow activating pair wise comparison in accordance with an internal principle.

With this aim, the SCBA presents a new approach to the traditional Cost-Benefit Analysis (CBA), adding new factors that are less assessable than economic benefits due to the medium-long term horizon of RTD market potential.

The new methodology proposes a hierarchical (or tree-based) structure of factors constituted by branches enabling the ranking and prioritization of the wide range of criteria at each level of the tree. This structure enables to frame the potential of the pacing technology by analysing new relations among branches to achieve an overall view of sustainability and ranking factors.

The SCBA framework, presented in this paper, identifies the AHP (Analytic Hierarchy Process) technique with sensitivity analysis as a suitable method for suitable investigation.

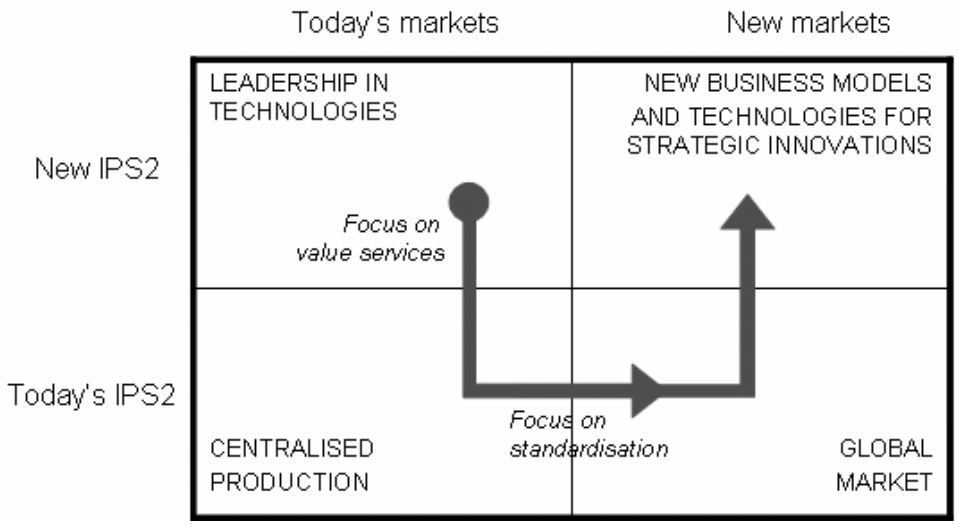

Figure 1: Scenarios for new IPS2 framework [4].

The main argument for the choice of AHP – compared to other multi-criteria decision-making techniques, including the multiple regression and multi-attribute utility approach as reported in the literature [16] [17] – lies in:

- its applicability to non-measurable criteria;
- more detailed and mixed information on pair wise comparison.

Its successful application to different decision-making problems – as reported in the literature [18] – and its appropriateness for the framework reported here are the reasons for adopting the AHP technique.

The above two features constitute the advantage of this technique's application regarding pacing technology development in next generation IPS2. In addition, the sensitivity analysis is incorporated into the evaluation methodology to test the stability of the priority ranking. In presence of market changes, stakeholders need the stability of a decision for the development and launch of next generation of IPS2 into new markets.

4 THE NEW APPROACH

The shorter life cycle of technologies and the fast introduction of new technologies into IPS2 require a new approach to the evaluation of IPS2 to support stakeholders in the investment decision.

In the traditional approach, Cost-Benefit Analysis (CBA) focuses on financial and economic aspects for analyzing prospective IPS2 ideas within an industrial innovation process. It accounts for all (negative and positive) effects of policy measures, allows comparison of the costs with the benefits of the proposal over time and can also be used to rank alternatives in order of their net social gains or losses. But this approach has some disadvantages:

- It cannot include impacts for which there exist no quantitative or monetary data.
- It presents difficulties in establishing the social discount rate.
- Usually it is more expensive and time-consuming than other, less broad, methods.
- It may lead to distributional issues being overlooked.

The SCBA approach presents new principles of CBA including the assessment of mixed (qualitative and quantitative) evaluation. This new approach responds to the need to evaluate pacing enabling technologies for potential next generation IPS2. This evaluation is based on market knowledge capture, introducing the competitive sustainable perspective and focusing the new 'science to market' relationship.

Market knowledge capturing for IPS2 regards coexistence or substitution of key with pacing technologies, to respond to competitive needs or to develop new markets looking forward to sustainability issues.

This approach evaluates the early impact of other aspects beyond the traditional economic and financial ones. It enables a costs and value benefits analysis for future market scenarios by integrating all production and consumption aspects. The concept of value benefits in the K-economy reinforces the view on present competition and enables future looking industrial innovation strategy. Recently, the importance of other factors, such as socio-political and environmental issues, has been also introduced at EU level, as mutually reinforcing the economic and financial decisions for market development studies.

Using appropriate decision-making techniques, this approach allows to build medium-long term assessment of pacing enabling technologies and expected next generation of IPS2:

- assessing impacts for which quantitative or monetary data do not exist;
- looking at a more relaxed approach towards benefits measurement;
- comparing alternatives between IPS that have more or less the same outcome and great value in use;
- exploring value benefits of important alternatives with the sensitivity analysis to assess the worth of decision implementation.

4.1 New factors

The SCBA approach presents new factors to evaluate the impact of the pacing enabling technology in terms of costs and value benefits and of new relationship among high technologies, producers-consumers, suppliers, regulations and society. The mainly profit seeking factors of competitiveness, just as economic and financial factors, are assessed together with social, political and environmental aspects responding to the Lisbon strategy objectives. The technological factor could be also considered as a key enabler, in particular in the context of strategic industrial fields, such as the space industry.

With this aim, the impact of pacing technologies is assessed across four policy dimensions (economic,

social, environmental and technological) that created the competitive sustainable manufacturing scenario.

In this context the costs and value benefits are evaluated by distinguishing between general and operational objectives. General ones attend to meet the overall goals of a strategy with global indicators that assess the outcome at a policy level. The evaluation in terms of general objectives is carried on at four dimensions levels. The operational objectives are expressed in terms of outputs, goods and services that the intervention should produce at management level. The evaluation in terms of operational objectives is carried on at sub-levels.

5 THE SCBA

Considering all the dimensions of competitive sustainable perspective and the turbulent market context of strategic industrial fields, the proposed theoretical framework requires a multi-criteria technique to support stakeholders in the innovation decision-making process, providing stable inputs for decisions.

With this aim, this paper presents a new methodology for Cost-Benefit Analysis – named SCBA (Sensitivity Cost-Benefit Analysis) – for the evaluation of potential IPS2 in medium-long term market scenarios.

The SCBA integrates sensitivity analysis with new principles of CBA. It supports stakeholders in evaluating costs and value benefits of pacing strategic enabling technologies by comparing them with a family of similar key technologies. The sensitivity analysis explores how the strategic and management decision of stakeholders changes in relation to variations in key parameters of existing technologies and in interactions. This technique supports industrial interests in the identification of decisions about value benefits, in order to make the option worth undertaking. SCBA analyses industrial interests for:

- Market competitiveness, making a comparison with existing products. The market demand for new features of next generation IPS2 is required for market success and not yet fully exploited by the existing IPS2.
- Targeted sustainability impact, which includes social and environmental requirements. The sensitivity analysis shows the outcome of the course of action in a medium-long time horizon.

5.1 Methods and tools

Methods and tools for the SCBA are structured to provide inputs coupled with knowledge management tools such as a structured survey made of consultation meetings with stakeholders and questionnaires.

In the theoretical framework presented here, a multi-criteria method is applied to evaluate the costs and value benefit of pacing enabling technology for next generation of IPS2, considering simultaneously several dimensions of competitive sustainable scenario.

The multi-criteria method covers a wide range of techniques that share the aim of combining a range of positive and negative impacts in a single framework to allow easier comparison of scenarios and decision-making. This method could be applied in order to consider a large amount of information on a number of different impacts and on different formats. It allows having a mixture of qualitative and quantitative information and of varying degrees of certainty.

Its applicability in the examined context presents the following advantages:

- simultaneous consideration of the multi-dimensionality of both competition and sustainability;
- evaluation and comparison of different types of data (quantitative and qualitative) in the same framework with varying degrees of certainty;
- transparent presentation of the key issues.

The theoretical framework, presented in this paper, identifies the AHP (Analytic Hierarchy Process) technique with sensitivity analysis as a suitable method for suitable investigation.

As reported in the references, the literature has compared several commonly used multi-criteria techniques. It shows that AHP, multiple regression and multi-attribute utility approach techniques produce similar results, but each one has advantages over the others. The advantages of AHP, represented by the detailed information produced and its applicability to non-measurable criteria, are the reasons for adopting the AHP method in this theoretical framework.

The AHP (Analytic Hierarchy Process) is a simple, mathematically-based, multi-criteria decision-making method that allows the presentation of results as a mix of measurable and qualitative criteria. The Analytic Hierarchy Process (AHP) is a structured technique for helping people deal with complex decisions. Based on mathematics and human psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then.

In the literature, AHP provides a comprehensive and rational framework for structuring a problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision-making techniques. Although AHP has been the subject of many research papers and the general consensus is that the technique is both technically valid and practically useful, there are critics of the method.

In the following, the SCBA methodology is applied to evaluate costs and value benefits focusing the pacing technologies that enable new directions for the European satellite industry. The study is ongoing and the evaluation analysis cannot be disseminated.

With the aim of market knowledge capture, knowledge management for innovation has integrated the evaluation analysis with:

- consultation meetings with stakeholders (producers and buyers);
- questionnaire to survey market key opinion leaders in terms of expectations both due to the present inefficiency of existing IPS2 and related enabling technologies and as future needs in a strategic perspective regarding the new factors change,
- pre-structure data and guidelines to target innovation and structured to lead potential consumers to express their needs.

At an operative level, in accordance to the application of AHP technique [19], the procedure for processing the stakeholder inputs starts from the building of a tree-based structure and provides the ranking of alternatives; at the end results are tested with sensitivity analysis:

Phase 1. Build the appropriate hierarchical structure (Figure 2).

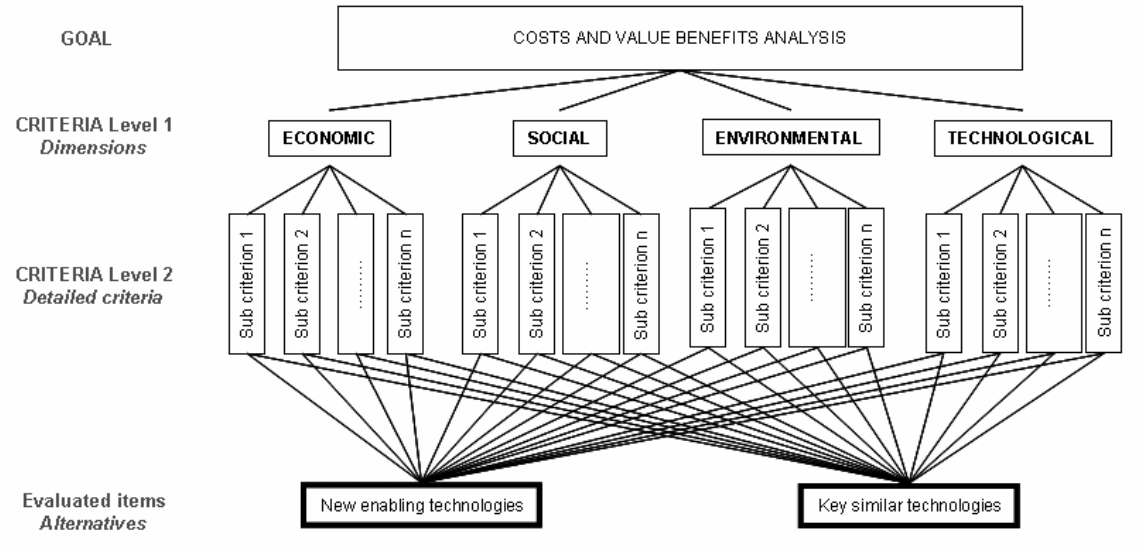

Figure 2: Costs and value benefits' hierarchy structure.

1. Goal: Analyse costs and value benefits of technologies within a competitive sustainable perspective.
2. Criteria. The multiple ranges of criteria are put in order in suitable and manageable groups.

- At level 1, there are represented four dimensions (D) of a competitive sustainable perspective: Economic, Social, Environmental and Technological.
- From level 2 to level N, the range of criteria (C) is grouped according to the proper competitive sustainable dimension. For example, under Technological dimension there are criteria of: operational aspects, technical requirements, state of the art,..

3. Alternatives (A). The evaluated items are: Pacing strategic enabling technologies vs. Key similar technologies.

Phase 2. Establish priorities and ranking at each level of the hierarchy structure. This analysis is based on stakeholders inputs which are captured through knowledge management tools (questionnaires, consultation,…) and interpreted using the nine-point scale (Figure 3).

1. Determine the importance of each D_m (with *m*=1,2,3,4) competitive sustainable dimensions with respect to achieving the overall objective. The four dimensions are compared pair wisely, using a nine-point scale. The comparison matrix $\boldsymbol{W_1}$ can be formed to represent the pair wise comparison of four dimensions. The matrix element

$$w_{ij} = w_i / w_j \qquad (1)$$

represents the weights of dimension D_i respect to dimension D_j. The consistency index and consistency ratio need to be checked. At the end of this comparison the local ranking (that in the first level is also global ranking) of dimensions is built.

$$W_1 = \begin{array}{c} \\ D_1 \\ D_2 \\ D_3 \\ D_4 \end{array} \begin{array}{c} \begin{array}{cccc} D_1 & D_2 & D_3 & D_4 \end{array} \\ \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \frac{w_1}{w_3} & \frac{w_1}{w_4} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \frac{w_2}{w_3} & \frac{w_2}{w_4} \\ \frac{w_3}{w_1} & \frac{w_3}{w_2} & \frac{w_3}{w_3} & \frac{w_3}{w_4} \\ \frac{w_4}{w_1} & \frac{w_4}{w_2} & \frac{w_4}{w_3} & \frac{w_4}{w_4} \end{bmatrix} \end{array}$$

2. Determine the importance of each criterion $C_{n(m)}$at each level (from 2 to N) with respect to its upper-level dimension using the nine-point scale. At level 2, four different matrices are built, each one for the m dimensions. The consistency indexes and consistency ratios need to be checked. At the end of this comparison the local priorities for each group of *n* criteria at second level are constructed. Multiplying the local weight by the global weight of the upper level the global ranking is also obtained.

$$W_{1m} = \begin{array}{c} \\ C_{1(m)} \\ C_{2(m)} \\ \dots \\ C_{n(m)} \end{array} \begin{array}{c} \begin{array}{cccc} C_{1(m)} & C_{2(m)} & \dots & C_{n(m)} \end{array} \\ \begin{bmatrix} \frac{w_{1(m)}}{w_{1(m)}} & \frac{w_{1(m)}}{w_{2(m)}} & \dots & \frac{w_{1(m)}}{w_{n(m)}} \\ \frac{w_{2(m)}}{w_{1(m)}} & \frac{w_{2(m)}}{w_{2(m)}} & \dots & \frac{w_{2(m)}}{w_{n(m)}} \\ \dots & \dots & \dots & \dots \\ \frac{w_{n(m)}}{w_{1(m)}} & \frac{w_{n(m)}}{w_{2(m)}} & \dots & \frac{w_{n(m)}}{w_{n(m)}} \end{bmatrix} \end{array} \quad \text{for each } m$$

3. Obtain the priorities of alternatives with respect to each of the criteria. Then synthesizing the results of steps a) and b), multiplying the local weight by the respectively global weight the global ranking of alternatives is obtained.

$$\begin{array}{c} \\ A_{1(n)} \\ A_{2(n)} \end{array} \begin{array}{c} \begin{array}{cc} A_{1(n)} & A_{2(n)} \end{array} \\ \begin{bmatrix} \frac{w_{1(n)}}{w_{1(n)}} & \frac{w_{1(n)}}{w_{1(n)}} \\ \frac{w_{1(n)}}{w_{1(n)}} & \frac{w_{1(n)}}{w_{1(n)}} \end{bmatrix} \end{array} \quad \text{for each } n$$

Key assessment indicators		
Intensity of impact	Definition of the importance	Explanation
1	Equal	Two elements contribute equally to the objective
3	Moderate	Experience and judgement slightly favor one element over another
5	Strong	Experience and judgement strongly favor one element over another
7	Very strong	One element is favored very strongly over another
9	Extreme	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2,4,6,8 can be used to express intermediate values		

Figure 3: The fundamental scale for Pair wise Comparisons based on Scale of Saaty

Phase 3. Perform the sensitivity analysis. At the end of this process the sensitivity analysis is performed to test the stability of the priority ranking of alternatives in relation to variations in key parameters.

At the end of this procedure, the ranking of alternatives and criteria are obtained and an overall – but also detailed – view of sustainability and ranking factors is achieved. The most beneficial for innovation is the creation of new knowledge that supports stakeholders in the innovation decision-making processes, screening the multi-dimensions of sustainability as well as the issues of competitiveness.

By better analyzing the achieved results at each level, it is possible to capture market inputs for the development of next generation IPS2 and the related benefits in a short, medium and long term perspective. In addition, by analyzing the inputs of several classes of stakeholders, it is possible to define classes of potential users and support the organization on segmentation of market and selection of market clusters.

6 SUMMARY

This paper proposes the SCBA methodology for the assessment of costs and value benefits of emerging technologies and for market knowledge capture of new IPS2. This methodology has been produced by the Laboratory of Emerging Production Paradigms (EPPLab) of ITIA-CNR of the Department of Production Systems of the Italian CNR [20] within its strategic research project.

The main author of this paper is the head of EPPLab, Dr. Paci who wrote paragraphs 1, 2, 3, 4, 6. Eng. Chiacchio wrote paragraphs 5 within her PhD study on New Production Impact assessment in Economic and Management Engineering at the University of Rome “Tor Vergata”.

The proposed SCBA framework deals with emerging pacing technologies – as a driver of change – and their time to market diffusion. It considers emerging technologies as the enabler of high value features of next generation of IPS2 to meet competitive and sustainable issues.

SCBA frames new principles of Cost-Benefit Analysis within the AHP method and in the sensitivity analysis.

To this aim, SCBA provides elements for a comparison with existing competitive products analysing the producers-buyers market demand for new features not yet fully exploited by the existing IPS2.

Overall, SCBA targets to assess the sustainability impact, which includes social and environmental requirements. The sensitivity analysis shows the outcome of the course of action in a medium-long time horizon in order to make the option worth undertaking.

The evaluation results support stakeholders in the market knowledge capture about next generation IPS2 based on new enabling technologies.

Therefore, this new framework enables to build market-oriented scenarios for production and manufacturing of new high value products and services, meeting and mutually reinforcing competitiveness and sustainability.

7 REFERENCES

[1] Jovane, F., Yoshikawa, H., Alting, L., Boër, C.R., Westkämper, E., Williams, D., Tseng, M., Seliger, G., Paci, A.M., 2008, The incoming global technological and industrial revolution towards Competitive and Sustainable Manufacturing, CIRP General Assembly, Manchester, UK, 24-30 August in publishing in CIRP Annals.

[2] Westkämper, E., 2008, Manufuture and Sustainable Manufacturing, in publishing in CIRP Annals.

[3] Mont, O.K., 2002, Clarifying the concept of product-service system, Journal of Cleaner Production, 10: 237-245.

[4] ManuFuture ETP High Level Expert Group, 2004, ManuFuture: a Vision for 2020. Assuring the future of manufacturing in Europe, European Commission Research DG.

[5] Manufuture ETP High Level Group and Support Group, 2006, Strategic Research Agenda, assuring the future of manufacturing in Europe, European Commission Research DG.

[6] European Commission, 2008, Guide to Cost-Benefit Analysis of investment projects.

[7] European Commission, 2005, Impact Assessment Guidelines.

[8] Paci, A.M., Chiacchio, M.S., Lalle, C., 2008, Production Paradigm Ontology (PPO): a response to the need of managing knowledge in high-tech manufacturing, Methods and Tools for Effective Knowledge Life-Cycle-Management, Springer: 227-240.

[9] http://www.prs-pacific.eu/

[10] Navigate Consortium, 2007, ERA STAR Survey Navigate Consortium Lombardia Region Contribution.

[11] bavAIRia GMES, Bavarian Ministry of Economy Affairs, Infrastructure, Transport and Technology, 2006, Monitoring for environment and security – Bavaria's capabilities in GMES.

[12] http://www.isi-initiative.eu.org/.

[13] Corazza, G.E., Arcidiacono, A., Charrier, J.F., Fogliati, V., Leurquin, C., Piccinni, M., Saggese, E., Tjelta, T., 2006, The Integral Satcom Initiative: A Technology Platform for FP7, ASMS 2006 Conference.

[14] Paci, A.M., Transectoral technologies impact on sectors, 2007, Deliverable of the Leadership-SSA Project www.leadership-ssa.net.

[15] Paci, A.M., 2006, A collaborative industry-research frame for roadmapping, Production Engineering – Knowledge, Vision, Framework Programmes, Conference Proceedings, E. Chlebus (ed), Wroclaw, Poland, 7-8 December: 5-10.

[16] Tavana, M., 2004, A subjective assessment of alternative mission architectures for the human exploration of Mars at NASA using multicriteria decision making, Computers & Operations Research, 31: 1147–1164.

[17] Rezaei-Moghaddam, K., Karami, E., 2008, A multiple criteria evaluation of sustainable agricultural development models using AHP, Environ Dev Sustain, 10: 407–426 DOI 10.1007/s10668-006-9072.

[18] Chen, H.H., Kang, H.Y., Xing, X., Lee, A.H.I., Tong, Y., 2008, Developing new products with knowledge management methods and process development management in a network, Computers in Industry, 59: 242–253.

[19] Saaty, T.L., The Analytic Hierarchy Process, 1980, McGraw-Hill, New York.

[20] Brochure EPPLab, 2008 http://www.itia.cnr.it/docs/EPPlableafletitaottobre2007.pdf.